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June 16, 2015

EX PARTE VIA ECFS

Ms. Marlene H. Dortch
Secretary
Federal Communications Commission
445 12th Street, S.W.
Room TW-A325
Washington, D.C. 20554

Re: ***Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions,* GN Docket No. 12-268;**
***Comment Sought on Competitive Bidding Procedures for Broadcast Incentive Auction 1000, Including Auctions 1001 and 1002,* AU Docket No. 14-252**

Dear Ms. Dortch:

On June 12, 2015, representatives of T-Mobile US, Inc. (T-Mobile) and United States Cellular Corporation (US Cellular) met with members of the Federal Communications Commission's Incentive Auction Task Force.[1] Representatives for T-Mobile and US Cellular reviewed the attached slide presentation and discussed the companies' joint proposal to apply a deferred acceptance algorithm, or more properly, a serial priority-assessment algorithm to the assignment phase of the incentive auction. During their meeting, the representatives of T-Mobile and US Cellular expressed the companies' strong support for adopting a non-monetary mechanism to assign specific licenses in the incentive auction. Adopting such a mechanism will increase not only the pool of funds available for paying broadcasters, but also the likelihood of clearing more spectrum for broadband use.

[1] T-Mobile USA, Inc. is a wholly-owned subsidiary of T-Mobile US, Inc., a publicly traded company. Meeting participants included Kathleen Ham and Steve Sharkey of T-Mobile; Gregory Rosston and Andrzej Skrzypacz (by phone), consultants to T-Mobile; Trey Hanbury of Hogan Lovells US LLP, counsel to T-Mobile; Grant Spellmeyer of US Cellular; Joseph Hanley of US Cellular's parent company, TDS; Leighton Brown of Holland & Knight LLP, counsel to US Cellular; Robert J. Weber, consultant to US Cellular; Martha Stancil, Chris Helzer, Karen Sprung, Joel Taubenblatt, Jim Schlichting, Gary Epstein, Howard Symons, and Melissa Dunford of the Federal Communications Commission; and Paul Milgrom (by phone), Ilya Segal (by phone), Larry Ausubel, Oleg Baranov (by phone) of Power Auctions, consultants to the Commission.

The companies' joint proposal, which would operate only after application of the contiguity optimization features the Commission proposed in its Comment Public Notice, has three critical ordering and prioritization features.[2] First, the Commission would randomly rank-order the winning bidders. Second, each winning bidder from the clock phase of the forward auction would prioritize every Partial Economic Area (PEA) in which it won generic licenses from the most important to the least important to that bidder. Third, each winning bidder would prioritize its feasible block assignments within each PEA from the most to the least desirable for its business plan. After completion of these ordering and prioritization features, the Commission would follow the randomly selected rank-order of bidders, choose bidder 1's highest priority PEA for the first assignment round, and award bidder 1 its preferred license assignments within that PEA. The Commission would then cycle through the other bidders' respective PEA prioritizations and license preferences in a logical fashion until all licenses were assigned.

As explained in the joint economic study, the proposed serial priority-assessment algorithm has many desirable qualities, the foremost of which is to push revenue into the clock phase of the forward auction, where it can be used to cover broadcast exit and clearing expenses, thereby maximizing the amount of spectrum recovered, rather than have bidders reserve funds for the assignment phase.[3] In an assignment phase "auction" where the winning bidder *must* get one or more licenses, the value that any one bidder will pay during the clock phase is defined by the premium that the winning bidder would be willing to pay to obtain its preferred assignment instead of the worst possible assignment that the bidder could receive. Bidders faced with this situation will rationally withhold bidding during the clock phase to protect against the possibility of being left with the least desirable license during the assignment phase. Commenters addressing the issue are unanimous in agreeing that assignment phase bidding will decrease revenues in the clock phase of the forward auction, which, in turn, will deplete the pool of funds available for broadcaster payments and could clear less spectrum for broadband use.[4]

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[2] *See Comment Sought on Competitive Bidding Procedures for Broadcast Incentive Auction 1000, Including Auctions 1001 and 1002*, Public Notice, 29 FCC Rcd. 15750, 15813-15 ¶ 199-209 (2014).

[3] For the full assignment phase proposal of T-Mobile and US Cellular, *see Comments on the Assignment Round* (June 11, 2015), *attached to* Letter from Trey Hanbury, Counsel for T-Mobile US, Inc., to Marlene Dortch, Secretary, Federal Communications Commission, GN Docket No. 12-268, AU Docket No. 14-252 (June 11, 2015). A copy of the proposal is also attached to this submission.

[4] *See, e.g.*, Robert Weber, *The Danger of Using a VCG-Style Auction for the Assignment Phase of the Forward Auction* (March 26, 2015), *attached to* Letter from Leighton T. Brown, Counsel for United States Cellular Corp., to Marlene Dortch, Secretary, Federal Communications Commission, GN Docket No. 12-268, AU Docket No. 14-252 (March 26, 2015); *Bidding Procedures for the Broadcast Incentive Auction* (April 22, 2015), *attached to* Letter from Leighton T. Brown, Counsel for United States Cellular Corp., to Marlene Dortch, Secretary, Federal Communications Commission, GN Docket No. 12-268, AU Docket No. 14-252 (April 22, 2015); Philip Haile, *Comments on U.S. Cellular's Assignment Phase* (May 15, 2015), *attached to* Letter from Christopher T. Shenk, Counsel to AT&T, to Marlene Dortch, Secretary, Federal Communications Commission, GN Docket No. 12-268, AU Docket No. 14-252 (May 15, 2015); Reply Comments of T-Mobile USA, Inc., AU Docket No. 14-252, GN Docket No. 12-268 (March 13, 2015); Comments of Competitive Carriers Association, AU Docket No. 14-252, GN Docket No. 12-268 (February 20, 2015).

An additional challenge with assignment phase bidding in the incentive auction is that it requires the bidders to form specific valuations for the different assignments within each PEA, which is difficult and time-consuming. Under the T-Mobile/US Cellular proposal, however, a bidder need only rank its potential block assignments through assigning ordinal preferences to the available options. Moreover, bidders frequently *will not know* during the clock phase of the forward auction the worst post-optimization assignments they could receive. Because the worst possible assignment in the incentive auction is unknown and potentially unknowable, bidders will find it difficult to bid in the clock phase. The existence of assignment phase bidding will also make it difficult to manage budget allocations between the clock and assignment phases of the forward auction. Reserving funds for the assignment phase will reduce the funds available during the clock phase and could reduce the amount of spectrum recovered. Finally, valuing options in dollars is more time consuming for bidders than ranking options, an action bidders also would presumably undertake prior to assigning dollar values to these options. By the companies' estimates, dollar-based bidding would require twice as much running time as a serial priority-assessment algorithm. In other words, adopting a serial priority-assessment algorithm could cut the duration of the assignment phase in half, which could save the Commission and winning bidders many weeks of administrative time.

Pursuant to Section 1.1206(b)(2) of the Commission's rules, an electronic copy of this letter is being filed in the above-referenced dockets. Please direct any questions regarding this filing to me.

Respectfully submitted,

/s/ Trey Hanbury

Trey Hanbury
Counsel to T-Mobile USA, Inc.

EXHIBIT 1

An Example

The “Ordered Selections” Assignment Procedure

The Set-Up

There are seven PEAs: {A, B, …, G}.

Each PEA offers four licenses.

There are six bidders, {i, j, k, l, m, n}, each of whom has won single licenses in one or more of the PEAs.

The Preliminaries

	i	*j*	*k*	*l*	*m*	*n*
A	1	1		2		4
B	2	2		3	2	
C	3	3	4			3
D	4	5	1	1		
E	5	7	2		1	
F	6	6	3			2
G	7	4	5			1

The FCC generates a random ordering of the winning bidders:

It happens to be *i-j-k-l-m-n*.

Each bidder ranks the PEAs in which it has won licenses in order of “assignment importance.”

Each bidder also ranks all of its feasible assignments within each PEA in order of preference (not displayed).

An Iteration

	i	***j***	***k***	***l***	***m***	***n***
A	1	1		2		4
B	2	2		3	2	
C	3	3	4			3
D	4	5	1	1		
E	5	7	2		1	
F	6	6	3			2
G	7	4	5			1

Repeatedly, the rank-1 bidder's top-ranked PEA will be chosen, and that bidder will be given its most-preferred assignment in the chosen PEA. The following bidders will be given, in rank order, their most-preferred assignments in that PEA among all assignments that are still feasible.

Here, the rank-1 bidder is *i*.
The chosen PEA is PEA A.
The order of assignments is *i, j, l, n*.

The Start

	i	*j*	*k*	*l*	*m*	*n*
A	1	1		2		4
B	2	2		3	2	
C	3	3	4			3
D	4	5	1	1		
E	5	7	2		1	
F	6	6	3			2
G	7	4	5			1

The rank-1 bidder is bidder *i*, and its most-important PEA, A, is chosen.

Bidder *i* receives its most-preferred feasible assignment in PEA A. Then the assignment preferences of *j*, *l*, and *n* in PEA A are processed in order.

The First Continuation

	j	*k*	*l*	*m*	*n*	*i*
A	1		2		4	1
B	2		3	2		2
C	3	4			3	3
D	5	1	1			4
E	7	2		1		5
F	6	3			2	6
G	4	5			1	7

PEA A is now fully assigned. Bidder *i* moves to the end of the list.

The rank-1 bidder is now bidder *j*, and its most-important (remaining) PEA, B, is chosen.

The assignment preferences of *j*, *l*, *m*, and *i* in PEA B are processed in order.

Another Continuation

	k	*l*	*m*	*n*	*i*	*j*
A		2		4	1	1
B		3	2		2	2
C	4			3	3	3
D	1	1			4	5
E	2		1		5	7
F	3			2	6	6
G	5			1	7	4

PEA B is now fully assigned. Bidder *j* moves to the end of the list.

The rank-1 bidder is now bidder *k*, and its most-important (remaining) PEA, D, is chosen.

The assignment preferences of *k, l, i,* and *j* in PEA D are processed in order.

One Bidder is Done

	l	*m*	*n*	*i*	*j*	*k*
A	2		4	1	1	
B	3	2		2	2	
C			3	3	3	4
D	1			4	5	1
E		1		5	7	2
F			2	6	6	3
G			1	7	4	5

PEA D is now fully assigned. Bidder *k* moves to the end of the list.

The rank-1 bidder is now bidder *l.*

All of the PEAs where it has won licenses have already been processed. Bidder *l* can be removed from the table (although we'll keep it, for purposes of the example).

Continuing

	m	*n*	*i*	*j*	*k*	*l*
A		4	1	1		2
B	2		2	2		3
C		3	3	3	4	
D			4	5	1	1
E	1		5	7	2	
F		2	6	6	3	
G		1	7	4	5	

Bidder *l* moves to the end of the list.

The rank-1 bidder is now bidder *m*, and its most-important (remaining) PEA, E, is chosen.

The assignment preferences of *m, i, j,* and *k* in PEA E are processed in order.

Last Step Forward

	n	*i*	*j*	*k*	*l*	*m*
A	4	1	1		2	
B		2	2		3	2
C	3	3	3	4		
D		4	5	1	1	
E		5	7	2		1
F	2	6	6	3		
G	1	7	4	5		

Bidder *m* moves to the end of the list.

The rank-1 bidder is now bidder *n*, and its most-important (remaining) PEA, G, is chosen.

The assignment preferences of *n, i, j,* and *k* in PEA G are processed in order.

The Flip

	n	*m*	*l*	*k*	*j*	*i*
A	4		2		1	1
B		2	3		2	2
C	3			4	3	3
D			1	1	5	4
E		1		2	7	5
F	2			3	6	6
G	1			5	4	7

Bidder *n*, the original last-ranked bidder, remains in place. The original rank order is reversed.

The rank-1 bidder is now (again) bidder *n*, and its most-important (remaining) PEA, F, is chosen.

The assignment preferences of *n, k, j,* and *i* in PEA F are processed in order.

Near the End

	m	*l*	*k*	*j*	*i*	*n*
A		2		1	1	4
B	2	3		2	2	
C			4	3	3	3
D		1	1	5	4	
E	1		2	7	5	
F			3	6	6	2
G			5	4	7	1

Bidder *n* moves to the end of the list.

Bidders *m* and *l* are already fully assigned.

The End

	k	*j*	*i*	*n*	*m*	*l*
A		1	1	4		2
B		2	2		2	3
C	4	3	3	3		
D	1	5	4			1
E	2	7	5		1	
F	3	6	6	2		
G	5	4	7	1		

Bidders *m*, and then *l*, move to the end of the list.

The rank-1 bidder is now bidder *k*, and its most-important (remaining) PEA, C, is chosen.

The assignment preferences of *k, j, i,* and *n* in PEA C are processed in order.

Summary

	k	*j*	*i*	*n*	*m*	*l*
A		1	1	4		2
B		2	2		2	3
C	4	3	3	3		
D	1	5	4			1
E	2	7	5		1	
F	3	6	6	2		
G	5	4	7	1		

Bidders *i* and *m* get first choice in their top-ranked PEAs, and bidder *n* gets first choice in its top- and second-ranked PEAs.

Bidder *j* gets first choice in its second-ranked PEA, and bidder *k* gets first choice in its top-ranked PEA and a lower-rank PEA.

Bidder *l* gets to pick second twice and third once in the three PEAs where it won licenses.

<u>**EXHIBIT 2**</u>

Comments on the Assignment Round

Gregory Rosston, Andrzej Skrzypacz, & Robert J. Weber[1]

Improvements to the design of the assignment round for the Federal Communication Commission's 600 MHz auction will help to increase revenues in the clock round and the chances of satisfying the Final Stage Rule ("FSR").[2] In addition, the assignment round can increase the efficiency of spectrum use. This submission builds on the submissions by Robert Weber (on behalf of United States Cellular Corporation ("US Cellular")), Philip Haile (on behalf of AT&T, Inc. ("AT&T")), T-Mobile USA, Inc. ("T-Mobile"), Competitive Carriers Association ("CCA") and other parties that discuss a variety of non-monetary mechanisms for awarding licenses in the assignment round.[3] These submissions raise important issues regarding revenue

[1] Gregory Rosston is Deputy Director and Senior Fellow at the Stanford Institute for Economic Policy Research and Director of the Public Policy program at Stanford University. Andrzej Skrzypacz is the Theodore J. Kreps Professor of Economics at the Stanford Graduate School of Business and a Professor, by courtesy at the Department of Economics. Robert J. Weber is the Frederic E. Nemmers Distinguished Professor of Decision Sciences at the Kellogg School of Management, Northwestern University.

[2] As currently envisioned, the FSR has two components that must be satisfied. The first is an average price per MHz-pop benchmark; the second is a requirement that the proceeds be sufficient to cover certain costs to be funded from the proceeds of the auction. *See In the Matter of Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions*, Order, 29 FCC Rcd. 6567, 6578 (2014); *Comment Sought on Competitive Bidding Procedures for Broadcast Incentive Auction 100, Including Auctions 1001 and 1002*, Public Notice, 29 FCC Rcd. 15750, 15769-15774 (2014) ("*Comment Public Notice*").

[3] *See, e.g.*, Robert Weber, *The Danger of Using a VCG-Style Auction (or any other revenue-generating procedure) for the Assignment Phase of the Forward Auction* at 5 (March 26, 2015) *attached to* Letter from Leighton T. Brown, Counsel for United States Cellular Corp., to Marlene Dortch, Secretary, Federal Communications Commission, GN Docket No. 12-268, AU Docket No. 14-252 (March 26, 2015) (proposing to "allow bidders to express preferences without generating payments" by allocating a supply of points among the bidders); Bidding Procedures for the Broadcast Incentive Auction (April 22, 2015) *attached to* Letter from Leighton T. Brown, Counsel for United States Cellular Corp., to Marlene Dortch, Secretary, Federal Communications Commission, GN Docket No. 12-268, AU Docket No. 14-252 (April 22, 2015) (proposing either a 100 point-based bidding system in which each winner in the clock phase would be allocated a budget of points for use in selecting assignments, or the use of random or quasi-random license assignments); Philip Haile, *Comments on U.S. Cellular's Assignment Phase* (May 15, 2015), *attached to* Letter from Christopher T. Shenk, Counsel to AT&T, to Marlene Dortch, Secretary, Federal Communications Commission, GN Docket No. 12-268, AU Docket No. 14-252 (May 15, 2015) ("AT&T May 15 Ex Parte") (endorsing many aspects of a points system over other non-monetary alternatives, but awarding more points to those bidders with larger budgets); Reply Comments of T-Mobile USA, Inc., AU Docket No. 14-252, GN Docket No. 12-268 at iv (March 13, 2015) ("T-Mobile Reply Comments") ("using a quasi-random assignment process after applying

and efficiency and make relevant contributions to identifying the nature of the assignment problem that needs to be solved.

Background

Once the forward auction is complete, the auction system will attempt to maximize contiguity of spectrum assignments when a bidder wins more than one license in a PEA. The Commission has proposed an optimization approach that would pursue three objectives in the following order of priority: (1) maximize the number of multiple-block winning bidders that receive at least two contiguous blocks; (2) minimize the number of assigned blocks that are non-contiguous to the bidder's other blocks for bidders that won two or more blocks; and (3) maximize the number of bidders that are assigned only contiguous blocks.[4]

These optimization objectives are constructive, but incomplete in that not all preferences can be taken into account using any reasonable number of objectives. The ensuing assignment round should allow for an expression of these preferences, which arise because the licenses in a category in a PEA may not be perfectly homogeneous from the perspective of some bidders.[5] For example, there may be some divergence in the impairment levels of Category 1 licenses in a PEA. The Category 1 divergence in value is a maximum of 15% coverage differential; however, at least some of the differential in value will be accounted for by the automatic impairment

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limited frequency and geographic contiguity objectives could clear more spectrum for broadband use and result in a more equitable distribution of spectrum resources among auction participants than an assignment auction"); Comments of Competitive Carriers Association, AU Docket No. 14-252, GN Docket No. 12-268 at 38 (February 20, 2015) ("the Commission should establish a limited number of primary selection awards available to all carriers with provisionally winning bids: in essence, each carrier would receive ten or some other limited number of 'draft picks' to use on particular spectrum assignments").

[4] *Comment Public Notice* at 15814-15815.

[5] *See, e.g.,* Sprint Comment Public Notice Presentation at 3 (March 17, 2015) *attached to* Letter from Rafi Martina, Counsel, Sprint Corp., to Marlene H. Dortch, Secretary, FCC, AU Docket No. 14-252, GN Docket No. 12-268 (March 19, 2015). *But see* T-Mobile Reply Comments at 18-19 ("the [one-to-one impairment-to-price] discount . . . provides enough commonality among licenses to allow for generic license bidding").

discount of one percent from the winning bid price for every one percent of impairment. For Category 2 licenses, the divergence in coverage value could be greater, although the automatic impairment discount would still account for some of the differential in value.[6] In addition to percentage-impairment differentials, however, some parties may value specific licenses differently because of frequency and geographic adjacencies not already taken into account by the optimization objectives, or because of the detailed nature of the specific impairment. As a result, bidders may value the blocks as imperfect substitutes, even after application of the optimization objectives and payment adjustments.

Determining license assignments within PEAs

After the FCC has completed its initial assignments or constraints on assignments using its optimization objectives, we propose that every bidder submit a rank order for the package assignments for which it is eligible within each individual PEA (or PEA group).[7] The FCC would then run a form of a "deferred acceptance" algorithm within each PEA.[8] The FCC would determine a rank order of the winners in the given PEA. (We propose how to determine this

[6] We understand that while there is a wide band (15% - 50% impairment) for Category 2 licenses, the impairments may affect multiple licenses to a similar degree so that the licenses are unlikely to diverge in coverage value by the maximum amount.

[7] The Commission has proposed separately grouping "high-demand" PEAs with the same number of Category 1 and Category 2 blocks, where the same frequency blocks are in Category 2, and where the same bidders won the same quantities of Category 1 and Category 2 blocks and non-high-demand PEAs within a Regional Economic Area Grouping ("REAG") that satisfy that same criteria. *Comment Public Notice* at 15813-15814. For simplicity, this proposal refers to the assignment of PEAs but could be applied equally to PEAs or groups of PEAs. However, the Commission could elect to forego the grouping process altogether to maximize the benefits of the deferred acceptance process described here.

[8] Deferred acceptance algorithms are well accepted and have been used in many different settings around the world. *See, e.g.*, Atila Abdulkadiroğlu & Tayfun Sönmez, *Matching Markets: Theory and Practice*, Paper Prepared for 2010 World Congress of Econometric Society, *available at* http://bit.ly/1Bnuz39. Since its initial formulation more than fifty years ago, this algorithm has been refined for use in everything from making student assignments in public schools to organizing kidney-exchange programs. *See id.* at 41. Indeed, the Royal Swedish Academy of Sciences awarded the 2012 Nobel Prize in Economic Sciences in recognition of the importance of this type of practical solution for complex matching problems. *See, e.g.*, THE ROYAL SWEDISH ACADEMY OF SCIENCES, *Stable Matching: Theory, Evidence, and Practical Design*, *available at* http://bit.ly/1esuEha.

order below). Then the algorithm would follow a straightforward sequential method to match bidders with their preferred license assignments.

First, the system would allocate to the rank-1 bidder its preferred bundle from the set of bundles that are feasible for that bidder subsequent to the FCC's contiguity optimizations. This assignment could reduce the set of feasible assignments remaining for other bidders. Next, the system would look at the rank-2 bidder's preferences and allocate the most preferred remaining feasible bundle to that bidder. The system would continue to make assignments through the ranks until all of the licenses in the PEA are allocated.[9]

Using this type of well understood and widely accepted deferred acceptance algorithm has the following positive properties, assuming that bidders care about their own allocation and do not want to make it worse for competitors:

1) There is no revenue left in the assignment auction.

2) The allocation will be Pareto-efficient in the ordinal sense. That is, there could be no reallocation of the licenses that would make the winners better off without payments to them.

3) Bidders optimize their assignments by reporting preferences truthfully, which should make the assignment round much less complicated.

4) The deferred acceptance algorithm is widely used in other applications; therefore, this algorithm is less risky to use than other possible mechanisms that have undergone far fewer practical tests and applications.

Determining Order within a PEA

We propose to determine the order in which the FCC allocates the rank order of choosing rights across all PEAs, and at the same time to determine the order in which PEAs will be

[9] This mechanism is equivalent to a so-called "serial dictatorship allocation" with a quasi-random order and with the FCC's constraints on allocations used to satisfy the objective of frequency contiguity. For the algorithm, if some PEAs were grouped, they would be treated as one PEA.

processed, in the following way. Each bidder would be asked to rank all the PEAs in which it has won some licenses in terms of how important the allocation in that PEA is to that bidder. Then, the FCC would randomly pick a rank ordering of all of the winning bidders, 1…N.

To begin, bidder 1's ordered list of PEAs would be consulted to choose the first PEA in which the FCC will allocate licenses. The assignment-selection ordering in that PEA would be that bidder 1 chooses first, bidder 2 chooses second, bidder 3 chooses third and so on.

Next, the FCC would remove that now-fully-assigned PEA from all the bidders' ordered lists, and choose the PEA ranked highest by bidder 2. In that PEA, bidder 2 would then choose first, bidder 3 would choose second and so on, with bidder 1 following bidder N. (In other words, bidder 1 would now be at the bottom of the stack.)

When the procedure reaches bidder N, the FCC would choose the first remaining PEA in that bidder's ordered list, and bidder N would choose a feasible assignment. Bidder 1 would choose second in that PEA and so on.

In the following round, the FCC again would allow bidder N's ranking to determine the next chosen PEA, with the successive choices of assignments being made by bidder N, bidder N-1, bidder N-2, and so on. Bidder N-1 determines the next chosen PEA, within which choices are made in turn by bidder N-1, bidder N-2 and so on. The process continues in this manner until bidder 1 determines the next chosen PEA. After that, the original process starts all over again.[10]

Sample Application of Deferred Acceptance Model

An example may assist in understanding how the proposed rule would apply to the assignment round. Assume that there are seven PEAs (A, B, C, D, E, F, G), each with four

[10] Giving bidder N two successive first choices, and then continuing to work backwards towards bidder 1, mimics the manner (known as a "snake draft") in which fantasy football leagues strive for equity while running their player drafts. As the choice of PEA moves backwards, the use of the reversed order for the within-PEA assignment selections equalizes the number of times either of any two bidders precedes or follows the other.

licenses. For simplicity, assume that each bidder wins a single license in any PEA; however, the same logic would apply with multiple licenses. Assume further that there are six winning bidders, ordered *i, j, k, l, m, n* by the FCC's initial randomization. The winners across the seven PEAs are listed in the following table, together with the "importance ordering" each assigns to the PEAs in which it has won licenses.

	i	*j*	*k*	*l*	*m*	*n*
A	1	1		2		4
B	2	2		3	2	
C	3	3	4			3
D	4	5	1	1		
E	5	7	2		1	
F	6	6	3			2
G	7	4	5			1

Note that both *i* and *j* have licenses in each PEA and the others have licenses in two or more PEAs.

Bidder *i* is the rank-1 bidder, and its top-ranked PEA is A. *i* would get first choice in A; *j* would get second choice; *l* would get third choice; and *n* would get the final choice (if a choice somehow remained). Next, the FCC would choose PEA B, bidder *j*'s top-ranked remaining PEA. *j* would get first choice in PEA B; *l* would get second choice; *m* would get third choice; and *i* would get the final choice. *k*'s preference for PEA D would mean that licenses in that PEA would be assigned next in the order, *k, l, i, j*. All of bidder *l*'s preferred markets will have been assigned by its turn so the FCC would move to bidder *m* and assign PEA E in the order, *m, i, j, k*. Since bidder *n* has PEA G as its first unassigned choice, licenses in that market would be assigned next, in the order *n, i, j, k*. The next assignment would look again to bidder *n* and assign PEA F, in the order *n, k, j, i*. The final assignment would be PEA C in the order *k, j, i, n*.

Discussion

The deferred acceptance algorithm has many favorable properties. The algorithm has been proven to work well in practice many times in a variety of settings.[11] Application of a deferred acceptance algorithm in this case should elicit truthful revelation and return a fair allocation of resources in a timely manner.

For bidders who win in many markets, the procedure of choosing the order within a PEA will result in getting a fair share of high-picks and low-picks. We think it will also be a fair procedure for bidders who win in a few markets, especially if these are markets that are outside the very top ones. We expect that bidders with many winnings will rank the largest (by population) markets the highest to increase their chances of getting the "first pick" in them. If so, even if a smaller winner is unlucky and receives a bad draw in the order of bidders, by the time the order reaches that bidder, it is unlikely that its most-preferred PEA would be already allocated.[12]

This ranking-PEAs method addresses the issue raised by Haile that bidders may vary in their strength of preference over allocations in different PEAs.[13] For example, if bidders A and B agree that in the Denver PEA license 1 is better than license 2 and in the Atlanta PEA license 1 is better than license 2, but for bidder A the allocation in Denver is more important while for

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[11] *See, e.g.,* Eric Gossett, *Discrete Mathematics with Proof* 7 (2009) (discussing use of deferred acceptance algorithms for college acceptances and medical residencies); Alvin Roth, *Deferred Acceptance Algorithms: History, Theory, Practice and Open Questions* at Table 1 (2007), *available at* http://bit.ly/1G0aJCr (listing the use of deferred acceptance algorithms in the labor market for a variety of professions, including pediatric dentistry, abdominal transplant surgeons, law firms, psychology, and other professions).

[12] At some additional cost of complexity, the Commission could augment the proposed algorithm to further reduce risk by, for example, increasing the chances that a bidder would choose second if given the selections so far, it had chosen second less often than expected based on the proposed algorithm.

[13] Philip Haile, *Comments on U.S. Cellular's Assignment Phase* at 8 (May 15, 2015), *attached to* AT&T May 15 Ex Parte.

bidder 2 the allocation in Atlanta is more important, the ranking PEAs method will allow them to express this preference and achieve more efficient allocation than choosing the order randomly.

As discussed above, deferred acceptance algorithms are widely used and adapted given their fast runtimes, broad applicability, and simplicity.[14] While bidders will need some amount of time to develop their preferences for all of the possible license combinations after the end of the clock round, this process can be accelerated. If the Commission were to release to each bidder the set of possible allocations after it has run its initial assignment process, for example, bidders would be able to focus on the set of licenses that are possible and to reduce the amount of time necessary between the end of the clock phase and the start of the assignment phase.[15]

It also may help bidders to know the outcomes of some of the PEA assignments before they submit preferences for subsequent licenses. For example, AT&T seems to view frequency contiguity over a geographic area as an important value.[16] As a result, knowing that it has frequency A in one PEA could change its preferences in adjacent PEAs.

In terms of timing, the algorithm we are proposing faces the same trade-offs as any other assignment procedure, including a point-based system and an assignment auction. On the one hand, it would be beneficial to perform the process quickly to reduce administrative costs. On the other hand, winners' preferences over allocations in a given PEA may depend on the allocations they receive in adjacent PEAs. The process we propose is flexible in responding to these concerns: the Commission could run the process sequentially, only asking the winners to provide rankings for the current PEA after the initial winners observe their own allocations in the

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[14] *See, e.g.,* Christian Haas, *Incentives and Two-Sided Matching: Engineering Coordination Mechanisms for Social Clouds,* 147 (1st ed. 2014), *available at* http://bit.ly/1ArW3tB.

[15] *See, e.g.,* Reply Comments of AT&T, AU Docket No. 14-252, GN Docket No. 12-268 at 4-5 (March 13, 2015).

[16] AT&T May 15 Ex Parte at 2-3.

previous PEAs. Conversely, bidders could be asked for all their rankings at once and then the system would run automatically in seconds. We support a sequential approach, but also recognize the possible efficiency advantages of a hybrid approach, which would allow sequential allocation in a few major PEAs to anchor preferences in different geographical regions and then ask winners to provide rankings simultaneously for multiple PEAs.

Conclusion

Matching theory as identified in deferred acceptance algorithms offers stable, well-developed mechanisms to efficiently and equitably solve otherwise complex preference-ordering challenges. The FCC should rely on this established body of literature to adopt a deferred acceptance algorithm such as the one proposed here. Doing so will allow the FCC to address the matching challenges posed by the 600 MHz Band in the incentive auction's assignment round.